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[Contact Us](#) | [Print Version](#)

[EPA Home](#) > [Research & Development](#) > [National Center For Environmental Research](#) > [Science Topics](#) > Global Change: Background



Search NCER Research Projects:

Search NCER Website:

[Advanced Search](#)

Which [search](#) is right for me?

Science Topics: Global Change: Background

Background

[Solicitations](#)

[Recipients
and their
Research
Projects](#)

[Research
Results](#)

[Program
Reviews
and
Evaluations](#)

Funding
Opportunities
Guidance & FAQs
Grants
Fellowships
Small Business
Research Centers
Other Programs
EPSCoR
ETOP
P3
Nanotechnology

Research Results
Science Topics

About NCER
Publications &
Proceedings

Events

Search

Personalize

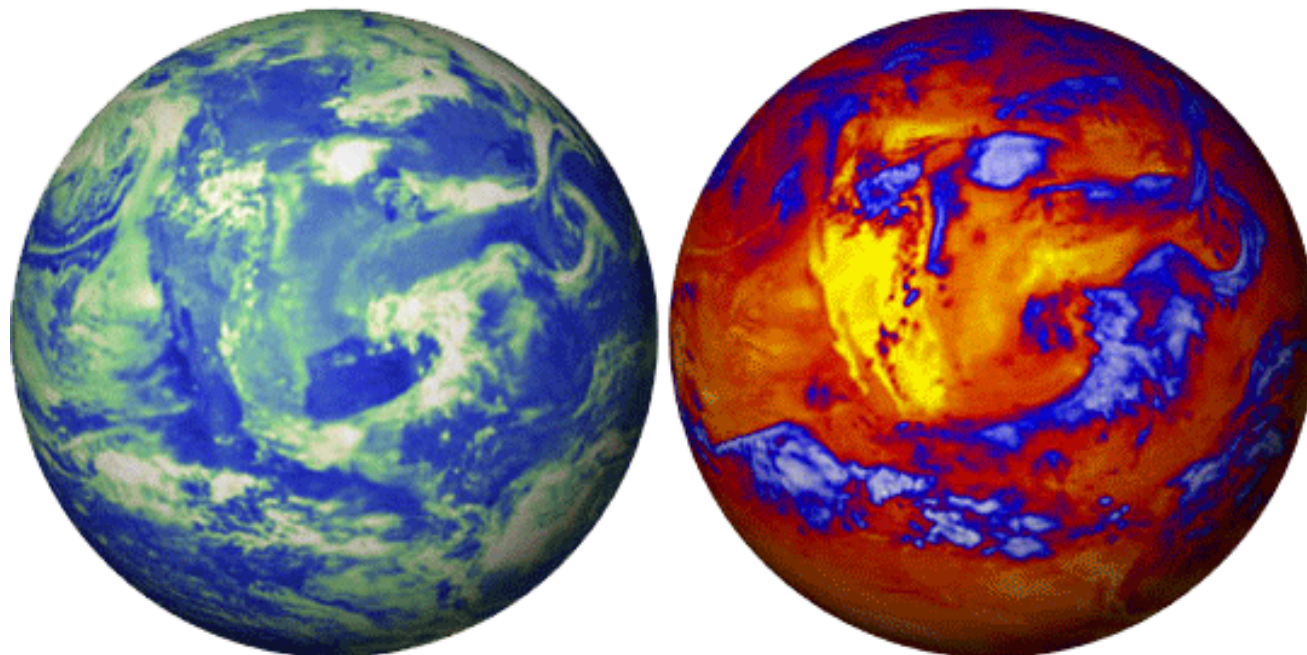
[NCER](#)
[Factsheets/](#)
[Other Pubs](#)

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Related
NCER
Research**

**External
Partnership
Projects**

**Print Entire
Document**
(PDF,
288pp., 4.02
MB, [about](#)
[PDF](#))

[Return to](#)
[Science](#)
[Topics](#)



Scientists have observed a warming trend across the Earth since the late 19th century, with the most rapid warming occurring over the past two decades. If emissions of greenhouse gases continue unabated, some scientists say humans may change global temperature and the planet's climate at an unprecedented rate. However, many questions remain about the cause, pace and consequences of these changes.

NCER's STAR program is working towards EPA's research goal of understanding the possible consequences of global change on human health, ecosystems and social well-being.

The purpose of the Global Change Research Program (GCRP) is to provide scientific information to stakeholders and policy makers in order to support them as they decide whether and how to respond to the risks and opportunities presented by global change.

Over the next decade, the GCRP plans a series of research and assessment activities culminating (in FY 2010) in a multi-sector, multi-region assessment in the consequences of global change in the U.S.

The emphasis of the GCRP's research and assessment strategy is on understanding the risks and opportunities presented by global change, the interdependent and interactive effects of multiple stresses, the human dimensions of global change (human activities that catalyze as well as those that respond to global change), and adaptation options.

The program has four focus areas of emphasis: (1) human health, (2) ecosystem health, (3) air quality, and (4) water quality.

NCER focuses on advancing the science to support assessments of the consequences of global change and human dimensions research. Current plans focus on the impacts of global change on air quality and on ecosystems.

Ecosystem Health Focus Area

The EPA Global Change Research Program conducts assessments of the effects of global change on aquatic ecosystems (freshwater and coastal) and their services. Assessments are conducted in the context of other stressors and human dimensions (social, economic and technological drivers) to improve society's ability to respond and adapt to the future consequences of global change. Global change includes climate variability and change, land use change. "Ecosystem services" describes both the conditions and the processes through which ecosystems sustain and fulfill human life. Ecosystem services maintain biodiversity, produce goods, and perform life-support functions.

The academic and stakeholder communities recognize the impact of global changes on aquatic ecosystems as an important area for research and assessment because of the goods and services that these ecosystems supply. Research gaps broadly include a need to understand how global change stressors affect the physical, chemical, and biological characteristics of aquatic ecosystems and their services, and how specific human adaptive responses will affect environmental outcomes. Thus, predictive models and climate change scenarios integrated with other process models that incorporate multiple stressors, are designed to support projections of future ecosystem status, and examine feedbacks between human and ecological responses. GCRP is addressing several of these needs including:

1. Landscape planning models that ascertain impacts of development on a changing landscape.
2. Terrestrial and aquatic natural ecosystem responses to multiple stresses, including the consequences for productivity, biodiversity, and other ecosystem processes and services.
3. Interactions of climate, UV, land cover, and land use in nutrient cycling, water supply and quality, and runoff.
4. Models of ecosystem disturbance, and species dispersal and recruitment.

The Ecosystem Focus Area long-term goal is that “decision makers in the states and EPA regional and program offices will use scientific information and decision tools from EPA’s research and assessment program to protect aquatic ecosystems by adapting to global change”. Ecosystem assessments support multiple EPA strategic goals, including: Goal 4: Healthy Communities and Ecosystems. Likewise, assessments support EPA’s Office of Water in fulfilling their responsibilities under the Clean Water Act whose goal is to “restore and maintain the chemical, physical and biological integrity of the Nation’s waters”.

Improving air quality is a major goal of the Agency and there is increasing recognition that climate and air quality are closely coupled through atmospheric chemical, radiative, and dynamic processes. While few studies have explicitly investigated the effects of global change on air quality, available evidence raises concerns that global change could adversely affect air quality. These studies suggest that global change could have significant impacts on ambient air quality. Changes in meteorology may affect air pollution levels by altering 1) rates of atmospheric chemical reactions and transport processes; 2) anthropogenic emissions, including adaptive responses involving increased fuel combustion for power generation (e.g. increased use of air conditioning); and 3) biogenic emission rates from natural sources. Patterns of land use can influence biogenic and anthropogenic emissions (e.g., increased urban sprawl may result in higher emissions from transportation sources or construction that lead to fugitive dust).

One of the long-term goals of EPA's GCRP is that air quality managers and decision makers in the states and EPA regional and program offices will use scientific information and models from EPA's research and assessment program to evaluate and implement adaptation policies that protect air quality from the impacts of global change. This goal will be accomplished through a series of projects building towards an ability to analyze the relationship between global changes and air quality. To address this issue, the GCRP is conducting a scenario-based assessment of the potential consequences of global change on regional US air quality, focusing on fine particles and ozone. The continuing research builds towards a 2007 assessment of changes in US air quality due to climate change, which includes direct meteorological impacts on atmospheric chemistry and transport and the effect of temperature changes on air pollution emissions. Further research will result in a 2010 assessment that adds the emission impacts from technology, land use, and demographic changes to construct plausible scenarios of US air quality 50 years into the future.

Ecosystem goals include research global change impacts on aquatic ecosystems by developing and applying methods for linking global changes to local changes in physical, chemical, biological and ecological conditions in selected watersheds.

[Return to the top](#)

[Research Opportunities](#) | [Guidance & FAQs](#) | [Grants](#) | [Fellowships](#) | [Small Business](#) | [Research Centers](#) | [Other Programs](#)
[Research Results](#) | [Science Topics](#)
[About NCER](#) | [Publications](#) | [Events](#) | [Search](#) | [Personalize](#)

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[Contact Us](#) | [Print Version](#)

[EPA Home](#) > [Research & Development](#) > [National Center For Environmental Research](#) > [Science Topics](#) > Global Change: Solicitations

Funding
Opportunities
Guidance & FAQs
Grants
Fellowships
Small Business
Research Centers
Other Programs
EPSCoR
ETOP
P3
Nanotechnology

Research Results
Science Topics

About NCER
Publications &
Proceedings

Events
Search



Search NCER Research Projects:

Search NCER Website:

[Advanced Search](#)

Which [search](#) is right for me?

Science Topics: Global Change: Solicitations

[Background](#)

Solicitations

- [Previous NCER Global Climate Solicitations](#)
- [Research Questions posed by our Solicitations](#)

[Recipients and their Research Projects](#)

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2004:

- [Effects of Climate Change on Ecosystem Services Provided by Coral Reefs and Tidal Marshes](#)
- [Fire, Climate and Air Quality](#)
- [Regional Development, Population Trend, and Technology Change Impacts on Future Air Pollution Emissions](#)

2003:

Personalize

[Research Results](#)

[Program Reviews and Evaluations](#)

[NCER Factsheets/Other Pubs](#)

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[Return to Science Topics](#)

- [Consequences of Global Change for Air Quality: Spatial Patterns in Air Pollution Emissions](#)

2002:

- [Assessing the Consequences of Global Change for Air Quality: Sensitivity of U.S. air quality to climate change and future global impacts](#)
- [Developing Regional-Scale Stressor-Response Models for Use in Environmental Decision-making](#)

2001:

- [Assessing the Consequences of Global Change for Aquatic Ecosystems: Climate, Land Use, and UV Radiation](#)

2000:

- [Assessing the Consequences of Interactions between Human Activities and a Changing Climate](#)

1999:

- [Integrated Assessment of the Consequences of Climate Change](#)

1997:

- [Terrestrial Ecology and Global Change](#)

1996:

- [Global Climate](#)

Research Questions posed by our Solicitations

January 2003 "Consequences of Global Change for Air Quality: Spatial patterns in air pollution emissions":

1. How would urban-rural population shifts, the use of smart growth approaches, and climate change affect the spatial distribution and amount of air pollution emissions?
2. How would technological change (including both the rate of technological change and diffusion), affect the amount and spatial allocation of anthropogenic emissions?
3. How would changes in sectors of the economy, for example shifts within and between manufacturing, service, and agriculture sectors, affect the amount and spatial distribution of air pollution emissions? Could climate change affect the economic changes and how can this be accounted for when spatially allocating emissions?
4. What methods can be used to project changes in land-use and activity locations (either caused by transportation infrastructure investments or otherwise) and how can they be incorporated in models that represent mobile source emissions? How might these models be improved to better reflect lifestyle and policy factors that drive vehicle miles traveled?
5. What are the important forces driving the transportation-relevant scenarios for economic, population, and land-use changes for the 2050 time horizon on local, state, and regional scales? How can the spatial and temporal specificity of these scenarios be improved?
6. How might spatial redistribution of activities and changes in land-use influence investments in transportation infrastructure and technology? Conversely, how might investment choices in transportation infrastructure and technology influence changes in

spatial distribution of activities and land-use change?

7. How will changes in climate (e.g. warmer temperatures or changes in humidity) affect emissions factors for pollutants from vehicles, refueling stations and fuel delivery systems? How will climate change affect the propensity to travel (both in aggregate and propensity to travel by particular modes)?
8. What is the nature of the linkage between growth in GDP and growth in transportation activity? What types of investments (e.g., transportation infrastructure, information technology) and policies are likely to lead to changes in this relationship? Will the impacts of present-day movements such as Smart Growth and the New Urbanism be significant enough to affect the linkage between transportation and economic growth, and, if so, under what circumstances?
9. What methods can be used to credibly project changes in the main drivers of land-use changes over long-time frames (e.g., to 2050 and beyond)? What are resulting patterns of land use (e.g., percent urban, agricultural, forest, etc.) in North America?
10. What are the implications of future patterns of urban growth and transportation networks and future climate change for agricultural, natural and managed vegetation species, range and health? What are the potential effects of urban reforestation?
11. What effects will predicted changes in climate (temperature, precipitation, drought, solar radiation), local air pollution, and landcover have on ecosystem and species-level biogenic VOC emissions? How will these factors, combined with changes in fertility management, impact soil NOX fluxes?
12. How will fire management and changes in wildfire distribution and intensity, along with plantation forestry, selective harvesting, and agricultural policy/practice, affect VOC and NOx emissions? How will PM2.5 emissions and precursors to SOA be impacted?
13. What uncertainties in current knowledge and biogenic VOC and NOx modeling systems limit the ability to use emissions algorithms to extrapolate biogenic emissions under future conditions? Can current light/temperature algorithms and emission factors be applied to vegetation growing in warmer, higher CO2 environments as has been attempted by Constable et al. (1999) and others?

May 2002 "Assessing the Consequences of Global Change for Air Quality: Sensitivity of U.S. air quality to climate change and future global impacts":

1. How is climate change, singly and in combination with future emissions, likely to impact ambient levels of ozone and particulate matter in the United States over the next 50 years?
2. How could changes in climate, such as those presented in the IPCC Third Assessment Report affect the intercontinental transport of ozone and particulate matter from Asia to the Western United States assuming emissions are unchanged? Which changes in climate (e.g., temperature, water vapor, circulation, etc.) are likely to be most important?
3. Considering future scenarios of economic growth, what impacts could be anticipated in intercontinental transport to North America of chemical species related to both ozone and particulate matter?
4. What is the overall impact of changes in the physical climate and future global emissions on U.S. air quality over the next 50 years?
5. Which aerosol species are most sensitive to changes in climate and are important for air quality modeling?
6. How significant are inter-model differences among General Circulation Models (GCM) for simulations of air quality changes?
7. What meteorological factors affected by climate change substantially alter ozone and particulate matter in U.S. urban areas? How large is the change in concentrations and in what direction for a specific change in meteorology?
8. How large a change in meteorological variables is needed to have a significant impact on ozone and particulate matter concentrations in the U.S.?
9. How sensitive are the predictions of the climate-related meteorological factors that most affect air quality to model uncertainty such as sub-grid parameterizations, climate-forcing boundary conditions, or process definitions?

10. What model uncertainties and emission uncertainties are significant concerns for simulating the fine particulate matter under climate change?

January 2002 "Developing Regional-Scale Stressor-Response Models for Use in Environmental Decision-making":

1. Are there significant interactions among multiple stressor effects or are the effects of common stressors, (e.g., suspended sediments, nutrients, pathogens, and altered habitat) additive?
2. Are there ranges of stressor concentrations at which significant interactions are expected to occur as different factors become limiting in a system? (For example, suspended sediments at high concentrations could mask the effect of eutrophication in an estuary, or a hydrologic regime characterized by frequent spates could prevent the accumulation of periphyton in a nutrient-rich system.)
3. Are the effects of common stressors additive along the headwater to estuary continuum or do different factors limit fish and shellfish populations within different aquatic resource classes and at different scales?
4. How might environmental change threaten ecosystem service integrity? What are the potential thresholds and breakpoints of ecosystem response to environmental change?
5. What is the uncertainty in the model predictions? How can model results be extrapolated from one place to another and from one timeframe to another? What are the geographical limits of the model?
6. Are data available to estimate the required model parameters? Are data available to test the model's predictions? How can the problem of limited data be dealt with? How can information be extrapolated across scales given data at different spatial and temporal levels of data resolution? For example, detailed time series data might be available for a limited number of targeted sites in a region within a matrix of probability-based samples used to characterize regional condition.
7. How will the model be tested and validated?

January 2001 "Assessing the Consequences of Global Change for Aquatic Ecosystems: Climate, Land Use, and UV Radiation":

1. How might climatic changes, in combination with UV radiation and/or changing land-use patterns, affect water quality, aquatic biodiversity, and ecosystem functioning?
2. How might changes in climate and land use affect the physical characteristics (e.g. stratification) of coastal and freshwater ecosystems? How then might the altered physical characteristics affect floral and faunal communities? (Investigators might consider changes in UV exposure, temperature and ice-free season, mixing dynamics, and chemical characteristics.)
3. How might changes in precipitation and temperature interact with current and future land-use choices, such as draining of wetlands, paving of surfaces, and channeling of streams and rivers, to affect water quality and UV exposure?
4. Could climatic and land-use changes result in changes in flooding, drought, base stream flow, and water quality, with implications for human health, social well-being, and aquatic ecosystems? Could watershed protection measures such as stream corridor restoration and wetland protection protect against negative impacts? How would these and other management options affect stream-flow, stream temperature, sediments loads, and other non-point source pollutants?
5. How might land-use choices increase or decrease vulnerability of aquatic ecosystems to extreme weather events?
6. How might interactive effects of climatic, UV, and land use changes affect water quality and ecosystem functioning through changes in biogeochemical cycling of nitrogen, phosphorous, and sulfur?

[Return to the top](#)

[Research Opportunities](#) | [Guidance & FAQs](#) | [Grants](#) | [Fellowships](#) | [Small Business](#) | [Research Centers](#) | [Other Programs](#)
[Research Results](#) | [Science Topics](#)
[About NCER](#) | [Publications](#) | [Events](#) | [Search](#) | [Personalize](#)

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National Center For Environmental Research

[Contact Us](#) | [Print Version](#)

[EPA Home](#) > [Research & Development](#) > [National Center For Environmental Research](#) > [Science Topics](#) > Global Change: Recipients and their Research Projects

Funding
Opportunities
Guidance & FAQs
Grants
Fellowships
Small Business
Research Centers
Other Programs
EPSCoR
ETOP
P3
Nanotechnology

Research Results
Science Topics

About NCER
Publications &
Proceedings
Events
Search



Search NCER Research Projects:

[Advanced Search](#)

Which [search](#) is right for me?

Science Topics: Global Change: Recipients and their Research Projects

Personalize

[Background](#)

[Solicitations](#)

**Recipients and their
Research Projects**

[Research Results](#)

**[Program Reviews
and Evaluations](#)**

**[NCER Factsheets/
Other Pubs](#)**

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Research**

**External Partnership
Projects**

**Print Entire
Document**
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**[Return to Science
Topics](#)**

2004:

[Effects of Climate Change on Ecosystem Services
Provided by Coral Reefs and Tidal Marshes](#)

[Fire, Climate and Air Quality](#)

[Regional Development, Population Trend, and
Technology Change Impacts on Future Air
Pollution Emissions](#)

2003:

[Consequences of Global Change for Air Quality:
Spatial Patterns in Air Pollution Emissions](#)

2002:

[Assessing the Consequences of Global Change
for Air Quality: Sensitivity of U.S. air quality to
climate change and future global impacts](#)

[Developing Regional-Scale Stressor-Response
Models for Use in Environmental Decision-making](#)

2001:

[Assessing the Consequences of Global Change
for Aquatic Ecosystems: Climate, Land Use, and
UV Radiation](#)

2000:

[Assessing the Consequences of Interactions
between Human Activities and a Changing Climate](#)

1999:

[Integrated Assessment of the Consequences of
Climate Change](#)

1997:

[Terrestrial Ecology and Global Change](#)

1996:

[Global Climate](#)

1995:

[Regional Hydrologic Vulnerability to Global
Climate Change](#)

[Return to the top](#)

[Research Opportunities](#) | [Guidance & FAQs](#) | [Grants](#) | [Fellowships](#) | [Small Business](#) | [Research Centers](#) | [Other Programs](#)
[Research Results](#) | [Science Topics](#)
[About NCER](#) | [Publications](#) | [Events](#) | [Search](#) | [Personalize](#)

Last updated on undefined, undefined NaNth, NaN
URL: <http://cfepa/ncer/science/globalclimate/recipients.html>



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National Center For Environmental Research

[Contact Us](#) | [Print Version](#)

[EPA Home](#) > [Research & Development](#) > [National Center For Environmental Research](#) > [Science Topics](#) > Global Change: Research Results

Funding
Opportunities
Guidance & FAQs
Grants
Fellowships
Small Business
Research Centers
Other Programs
EPSCoR
ETOP
P3
Nanotechnology

Research Results
Science Topics

About NCER
Publications &
Proceedings

Events
Search



Search NCER Research Projects:

[Advanced Search](#)

Science to Achieve Results
Search NCER Website:

Which [search](#) is right for me?

Science Topics: Global Change: Research Results

[Background](#)

[Solicitations](#)

[Recipients
and their
Research
Projects](#)

**Research
Results**

2003: [Consequences of
Global Change for Air
Quality : Spatial Patterns
in Air Pollution Emissions](#)

2002: [Assessing the
Consequences of Global
Change for Air Quality:
Sensitivity of U.S. air
quality to climate change
and future global impacts](#)

[Developing Regional-](#)

Personalize

[Program Reviews and Evaluations](#)

[NCER Factsheets/ Other Pubs](#)

Other Related NCER Research

External Partnership Projects

Print Entire Document
(PDF, 288pp., 4.02 MB, [about PDF](#))

[Return to Science Topics](#)

[Scale Stressor-Response Models for Use in Environmental Decision-Making](#)

2001: [Assessing the Consequences of Global Change for Aquatic Ecosystems: Climate, Land Use, and UV Radiation](#)

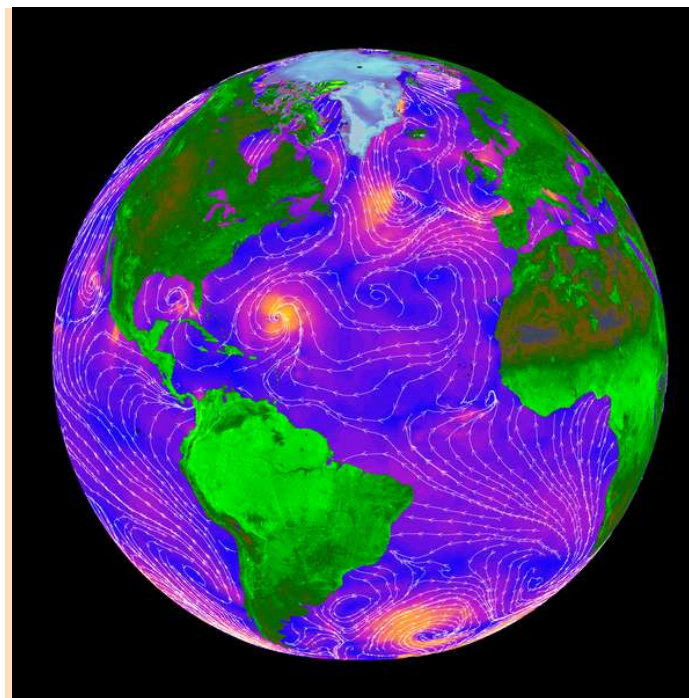
2000: [Assessing the Consequences of Interactions between Human Activities and a Changing Climate](#)

1999: [Integrated Assessment of the Consequences of Climate Change](#)

1997: [Terrestrial Ecology and Global Change](#)

1996: [Global Climate](#)

1995: [Regional Hydrologic Vulnerability to Global Climate Change](#)



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Examples of STAR Research Projects and Their Impacts

Climate Change Impacts on Florida Everglades Restoration

Since as early as the 1800s, more than half of the Florida's Everglades wetlands were lost to development, and water management practices designed to prevent flooding were sending valuable freshwater to sea. The Comprehensive Everglades Restoration Plan (CERP), a 20-year, \$7.8 billion plan, will capture freshwater destined for sea—the Everglades' lifeblood— and direct it back to the ecosystem to revitalize it. A team of scientists at the University of Miami is currently evaluating the potential effects of climate change on restoration efforts. Using cutting-edge computer models, researchers are manipulating stressors to evaluate potential impacts on conditions such as the flow of surface water and groundwater; the abundance and distribution of wading birds within the Florida Everglades; the freshwater inputs into Biscayne Bay and associated changes in salinity; the health of seagrass and bottom communities; and the size and behavior of fish populations. Results from this research will provide managers and scientists with new tools to better evaluate the potential effects of climate change on the performance of proposed restoration activities before they are implemented.

Modeling Global Change Impacts on Wildfire Cycles

A research team led by the University of Arizona is building a geographic information system (GIS) model that layers and integrates data for fire history, fuels and climate to produce wildland fire risk maps. Although the model, which focuses on four areas in the southwestern United States, is still in development, the project's website (<http://walter.arizona.edu>) is already providing useful information. The model and web-site have been enthusiastically received by fire managers attending the annual fire-climate workshop; the Interagency Wildfire Management Team in Los Alamos, New Mexico; and participants at the Arizona FIREWISE Communities workshop.

Global Climate Change Impacts on California's San Joaquin River Basin

The San Joaquin River Basin in California is the source of drinking water for more

than 20 million people in cities from San Francisco Bay to San Diego. It also supports one of the most important agricultural regions in the world. Researchers led by the University of California-Berkeley are assessing the vulnerability of the basin's water supply, ecological resources and rural economy to climate change and extreme weather. Results from this research have already produced a unique model that predicts effects of climate change on long-term agricultural productivity as a result of potential reduction in water supplies caused by climate change and soil salinity. This model is being used for resource planning activities.

[Return to the top](#)

[Research Opportunities](#) | [Guidance & FAQs](#) | [Grants](#) | [Fellowships](#) | [Small Business](#) | [Research Centers](#) | [Other Programs](#)
[Research Results](#) | [Science Topics](#)
[About NCER](#) | [Publications](#) | [Events](#) | [Search](#) | [Personalize](#)

[EPA Home](#) | [Privacy and Security Notice](#) | [Contact Us](#)

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[Contact Us](#) | [Print Version](#)

[EPA Home](#) > [Research & Development](#) > [National Center For Environmental Research](#) > [Science Topics](#) > Global Change: Program Reviews and Evaluations

Funding
Opportunities
Guidance & FAQs
Grants
Fellowships
Small Business
Research Centers
Other Programs
EPSCoR
ETOP
P3
Nanotechnology

Research Results
Science Topics

About NCER
Publications &
Proceedings
Events
Search



Search NCER Research Projects:

Search NCER Website:

[Advanced Search](#)

Which [search](#) is right for me?

Science Topics: Global Change: Program Reviews and Evaluations

Personalize

[Background](#)

[Solicitations](#)

**[Recipients and their
Research Projects](#)**

[Research Results](#)

**Program Reviews
and Evaluations**

**[NCER Factsheets/
Other Pubs](#)**

**Other Related NCER
Research**

**External Partnership
Projects**

**Print Entire
Document**
(PDF, 288pp., 4.02
MB, [about PDF](#))

**[Return to Science
Topics](#)**

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[Presentations](#)|

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STAR Consequences of Global Change for Air
Quality Progress Review Workshop
| [Announcement / Agenda](#) |

September 20 - 21, 2001

Global Change Progress Review Workshop
| [Proceedings](#)(PDF, 25pp., 409KB, [about PDF](#))|

September 25 - 27,2000

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| [Proceedings](#)(PDF, 11pp., 3.14MB, [about PDF](#)) |

September 13-14, 1999

STAR Integrated Assessments of Global Change
Progress Review
| [Proceedings](#)(PDF, 22pp., 270KB, [about PDF](#))|

[Return to the top](#)

[Research Opportunities](#) | [Guidance & FAQs](#) | [Grants](#) | [Fellowships](#) | [Small Business](#) | [Research Centers](#) | [Other Programs](#)
[Research Results](#) | [Science Topics](#)
[About NCER](#) | [Publications](#) | [Events](#) | [Search](#) | [Personalize](#)

[EPA Home](#) | [Privacy and Security Notice](#) | [Contact Us](#)

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National Center For Environmental Research

[Contact Us](#) | [Print Version](#)

[EPA Home](#) > [Research & Development](#) > [National Center For Environmental Research](#) > [Science Topics](#) > Global Change: NCER Factsheets/Other Pubs

Funding
Opportunities
Guidance & FAQs
Grants
Fellowships
Small Business
Research Centers
Other Programs
EPSCoR
ETOP
P3
Nanotechnology

Research Results
Science Topics

About NCER
Publications &
Proceedings
Events
Search



Search NCER Research Projects:

[Advanced Search](#)

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Personalize

[Background](#)

[Solicitations](#)

**[Recipients and their
Research Projects](#)**

[Research Results](#)

**[Program Reviews
and Evaluations](#)**

**NCER Factsheets/
Other Pubs**

**Other Related NCER
Research**

**External Partnership
Projects**

**Print Entire
Document**
(PDF, 288pp., 4.02
MB, [about PDF](#))

**[Return to Science
Topics](#)**

[Return to the top](#)

[Research Opportunities](#) | [Guidance & FAQs](#) | [Grants](#) | [Fellowships](#) | [Small Business](#) | [Research Centers](#) | [Other Programs](#)
[Research Results](#) | [Science Topics](#)
[About NCER](#) | [Publications](#) | [Events](#) | [Search](#) | [Personalize](#)

[EPA Home](#) | [Privacy and Security Notice](#) | [Contact Us](#)

Last updated on undefined, undefined NaNth, NaN
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